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JET PLATING OF HIGH MELTING POINT MATERIALS

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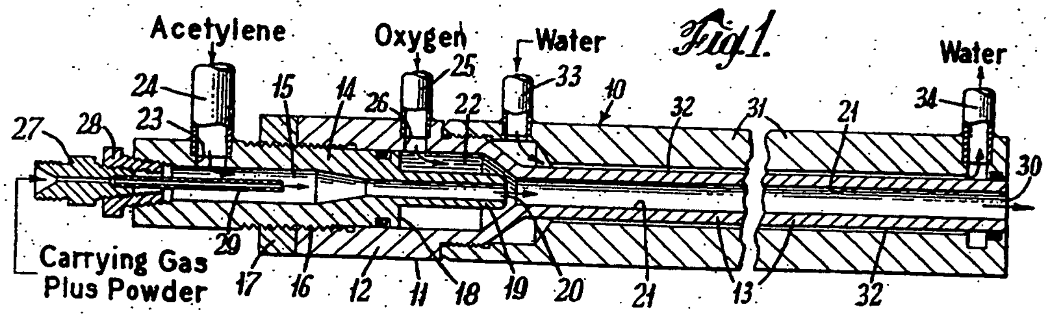

Fig. 1.

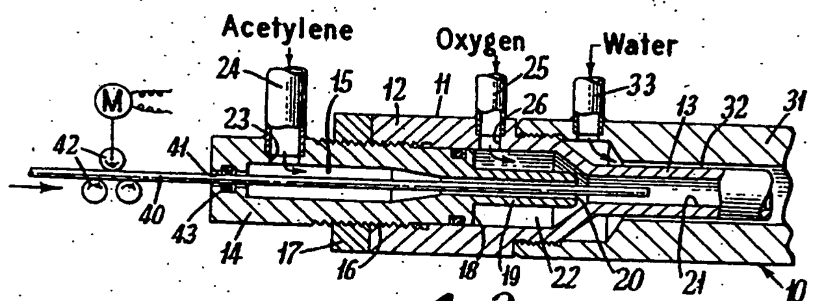

Fig. 2.

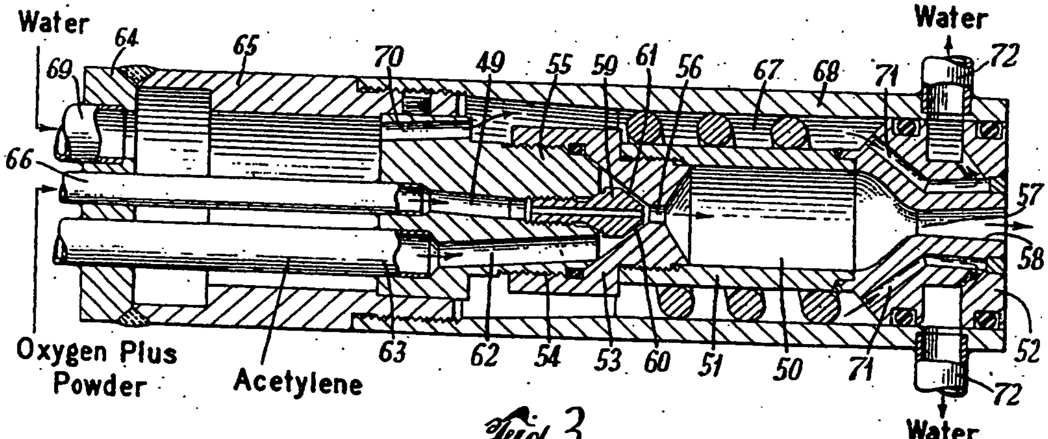

Fig. 3.

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JET PLATING OF HIGH MELTING POINT MATERIALS

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16 Claims. (Cl. 117—105)

The present invention concerns the application of improved surface coatings to objects and particularly relates to new and improved methods of and apparatus for flame spraying, which are especially advantageous for applying surface coatings of high melting point materials to articles.

For some time now, it has been common practice to provide an object with a protective coating by spraying the object with a melted and atomized material that would adhere to a pre-cleaned surface of the object. Surface spraying has been accomplished by introducing the coating material, usually in the form of a rod, into the flame of a gas burner in order to melt the material and by thereafter projecting the melted material against the surface to be coated by a blast of air or inert gas. Heretofore, such spraying has been practiced most successfully with the use of low melting point metals, and even these coatings have not been satisfactory for many applications, for they are usually porous and frequently unevenly distributed. As such, they lack many of the most desired properties of a good protective coating, such as for example, hardness for good wear resistance and imperviousness for corrosion resistance.

The present invention has the general purpose of overcoming the several limitations mentioned above of known surface spraying practices. Among the more particular objects are: To make feasible and practicable the use of higher melting point materials, as well as the usual low melting point materials for surface coatings. To reduce porosity in sprayed surface coatings so as to obtain increased wear and corrosion resistance in such coatings. And to improve hardness and strength characteristics by providing a wider range of available coating materials.

Still other objects of this invention are: To provide a continuous spraying operation utilizing high thrust to propel coating particles against the surface to be coated. To make practical the use of fuels with lower flame temperatures. To maintain the coating particles at relatively high temperatures during their travel to the surface of the workpiece without harm to the latter. And to increase the residence time of the coating material in the flame for a longer period than heretofore possible.

According to the present invention, there is provided a method of flame spraying a surface coating on workpieces, which includes bringing the coating material to a high temperature by introducing a fuel-oxygen mixture under pressure appreciably above atmospheric into a confined space where burning is initiated and introducing coating material into the combustion space, and thereafter propelling the heated particles toward the surface of the workpiece to be coated at temperatures and linear velocities greater than 500 feet per second such that the particles are at least at flowing temperature upon impact by discharging the burning gases through a portion of the confined space in which such gases are accelerated to exit velocities greater than 2000 feet per second, sufficiently high to impart such linear velocities to the particles. "Flowing temperature" may be defined as that temperature, determined by summing both the thermal

and kinetic energy of the material, at which the material or, at least, the lowest melting point constituent of such material becomes plastic. In the use of many coating materials, particularly metal and metal alloys and compounds, it is important to maintain the burning gases' composition non-oxidizing and non-decarburizing to the powder in order to produce a coating of desired quality.

The spraying operation is continuous and, in the preferred practice of this invention, comprises suspending comminuted solid material in a combustible mixture made up of a fuel and a combustion supporting agent in proportions that avoid an excessive oxidizing and decarburizing atmosphere upon combustion. The combustion supporting agent may be air but oxygen is preferred, particularly when plating high melting materials because of the higher flame temperatures produced with its use. Coating material may be introduced into the combustion zone by suspension either in the fuel or in the oxygen, or it may be suspended in the combustible mixture before or even after burning is initiated. The high flame temperatures and the high linear velocity of the flame jet essential to successful jet flame coating is obtained by passing the particle-carrying mixture to a burner of the internal combustion type where ignition of the mixture under pressure produces large volumes of flaming combustion gases that are discharged to the outside through a confining passageway that effects acceleration of the gases to high velocities.

The high temperatures to which the particles can be heated by being entrained in the combusting mixture and in the jet flame and the appreciable temperature increase corresponding to kinetic energy expended upon impact of the high velocity particles upon the surface of the work to be coated make it possible to melt even high melting point materials (or at least the lowest melting point constituent of such materials) sufficiently to insure a firm mechanical bond with the surface of the body to be coated. The high velocity imparted to the particles at these temperatures causes them to deform sufficiently upon impact to weld together to other particles in the coating so as to form a substantially non-porous coating. Moreover, in the method described above the thermal and kinetic energy of coating particles is sufficient so that the surface of the workpiece need not be heated to high temperatures, as in hard-facing, etc. Consequently, well bonded, non-porous coatings can be produced by the practice of this invention without causing major micro-structural changes in the workpiece.

These and other features, objects and advantages of this invention will become apparent from the following detailed description of the accompanying drawings, wherein:

Figure 1 shows a longitudinal cross-section through a preferred form of jet flame gun adapted for the practice of this invention; and

Figure 2 is a fragmentary section through a modification of the gun shown in Figure 1.

Figure 3 is a longitudinal cross-section through another form of jet flame gun suitable for the practice of this invention.

The method of the invention will now be described in detail in connection with the drawings, which show two embodiments of spray guns adapted for the practice of the invention.

With reference now to Figure 1, a spray gun, indicated generally at 10, is shown employing a "throat-combustion" burner 11, which is the type preferred in the practice of the present invention and which is similar in construction and operation to the burner disclosed in copending application, Serial No. 212,547, filed by George H. Smith on February 24, 1951. For purposes of this invention, a "throat-combustion" b

throat element constituted by a confined space unconstricted from inlet to outlet wherein a fluid combustible mixture received through such inlet at one end of the confined space is ignited within the passageway, passed through the confined space, and then discharged from the confined space through such outlet at the other end of the confined space as a stream of hot burning gases to produce a flame having a high heat transfer intensity, a high velocity and substantial thrust.

For satisfactory results, it is essential that conditions during combustion be maintained such that K is between 75 and 750 in the equation:

$$K=\frac{A_i^2 P_i^2}{A_o P_o W}$$

wherein:

A_i=cross-sectional area of said stream of fluid combustible material at the point of introduction thereof to said confined space, in square inches

A_o=cross-sectional area of said stream of burning combustible material at the point of discharge from said confined space, in square inches

P_i=pressure at the point of introduction of said stream of fluid combustible material into said confined space, in pounds per square inch absolute

P_o=pressure at the point of discharge of said stream of burning combustible material from said confined space, in pounds per square inch absolute

W=weight of fluid combustible material consumed, in pounds per second.

In detail, gun **10** comprises a burner **11** having a hollow cylindrical section **12** tapered at one end toward an integral elongated, centrally bored barrel **13** and open at its other end for the reception of a fuel injector **14** having a central passageway **15** axially aligned with the axis of barrel **13**. A threaded mid-section of the injector engages a tapped portion **16** of section **12**, the injector being held in preselected axial position in the burner by a lock nut **17**.

The injector **14** is stepped at **18** to provide a mixer section **19** of reduced diameter that lies in radially inwardly spaced relation to section **12** and terminates in an outlet **20** opening into the combustion throat **21** constituted by the bore of barrel **13**. The mixer **19** is spaced slightly from the tapered end wall of section **12** to provide an annular passageway for fluid flow from the annular space or chamber **22** around mixer **19** into the barrel **13**. A fuel feed line **24** is connected with passageway **15** through a lateral port **23**, and an oxygen feed line **25** is connected with chamber **22** through a lateral port **26**. In order to secure flashback of the flame, which is initially ignited outside the throat, into the throat **21**, the minimum diameter of the outlet **30** should not be substantially smaller than 0.02 inch.

Coating material may be introduced into the burner in comminuted form as a suspension in the fuel or in the oxygen or as a suspension in the combustible mixture. In the embodiment shown in Fig. 1, comminuted material is conveyed by a carrier gas, such as hydrogen, into a nipple **27**, threadedly received into the head of a centrally open adapter plug **28** that closes the rear end of passageway **15**. The nipple has its rear protruding end adapted to be connected to the source of coating material and has fitted into its forward end a forwardly extending hollow stem **29** that projects into passageway **15** at least beyond the lateral fuel feed port **23** and delivers carrier gas and entrained coating material to mixer section **19**.

Fuel and oxygen are supplied to the throat under pressure, preferably at least 15 pounds per square inch gauge. As the particle-carrying fuel enters the combustion throat **21**, it mixes intimately with the oxygen in the rear portion of throat **21** to form a stream of combustible mixture which starts to burn soon after mixing, producing large volumes of flaming combustion gases which pass forwardly at high velocities through the unconstricted confined space of the throat and are then discharged from outlet **30** at the mouth of barrel **13** as a flame jet. The coating particles entrained in the combustion gases are then ejected from the gun in a directed flame jet having a high heat transfer intensity, a high velocity and substantial thrust. In order to prevent excessive heating of the barrel **13** during operation, a sleeve **31** is disposed around the barrel in radially outwardly spaced relation to form a water jacket **32** through which cooling water can be circulated via inlet **33** and outlet **34**.

Coating material may also be introduced directly into the combustion zone in powder form or in the form of a rod. The latter is illustrated in Figure 2, wherein an elongated rod **40** of solid coating material is introduced through an opening **41** at the back end of the injector **14**, extends longitudinally therethrough, and projects from mixer **19** sufficiently forward into the rear portion of throat **21** that its forward tip lies in the combustion zone. The rod is moved positively by any suitable driving means, such as for example, oppositely rotating friction wheels, shown schematically at **42**, which engage opposite sides of rod **40**. An O-ring **43** serves to seal opening **41**.

It will be seen that a spray gun employing a throat combustion type burner has the unique advantage that the path of the particles throughout its passage through the confined combustion and discharge space is not constricted and, consequently, the particles meet no obstructions upon which they might lodge and cumulatively plug the passageway.

In a modified type of spraying gun shown in Figure 3, the burner employed is of the type where combustion occurs internally, in an enclosed chamber, and the flaming combustion gases are discharged from the combustion chamber through a jet nozzle. The gun comprises a combustion chamber **50** formed within a cylindrical shell **51** and a nozzle body **52** welded to the forward end of the shell. The combustion chamber **50** threadedly receives in its rear open end an injector member **53** which has at its end remote from the combustion chamber a tapped bore **54** into which an adapter **55** is threaded. The forward portion of bore **54** is tapered convergently toward a restricted injector throat **56** which forms an entrance into the relatively large combustion chamber **50**. The forward parts of the combustion chamber walls converge forwardly toward the throat **57** of a divergent discharge nozzle **58** whose exit passageway flares outwardly and forwardly.

An oxidizing agent such as gaseous oxygen with powdered coating material suspended therein is injected under pressure, preferably 15 pounds per square inch or more, through throat **56** into the combustion chamber **50** by an injector **59** which is threaded into an oxygen supply duct **49** centrally disposed in adapter **55**. Injector **59** projects into the tapered portion of bore **54** in axial alignment with throat **56** and combustion chamber **50** and terminates in a frusto-conical head **60** that is spaced from tapered walls of bore **54** to provide an annular passageway **61** for fluid from bore **54** into the throat **56**. A fuel such as acetylene is delivered concurrently but separately under pressure, preferably the same pressure as the oxygen, to the combustion chamber through an eccentrically arranged fuel supply duct **62** in adapter **55**, the open portion of bore **54**, passageway **61** and throat **56**. The fuel and coating-particle-carrying oxygen mix intimately together in passing through throat **56**, and the mixture under pressure burns vigorously in combustion chamber **50**, producing large volumes of flaming combustion gas which flow at high velocity through the nozzle **58**, carrying the coating particles with them. In this way the coating particles are entrained in the directed flame jet provided by the discharged gases, which imparts high linear velocity to the particles.

Fluid fuel is supplied to duct 62 through a tube 63 which extends from a header 64 through a sleeve 65 to the adapter 55 where it registers with duct 62. The particle-carrying oxygen is supplied to duct 49 through a tube 66 which extends from header 64 through sleeve 65 alongside tube 63 and is received in adapter 55 in registry with duct 49. A water jacket 67 is formed around the combustion chamber 50 and adapter 55 between the exterior wall of these members and an outwardly spaced sleeve 68 threaded at its rear end to sleeve 65. Cooling water is introduced into the jacket 67 through a conduit 69 in header 64, sleeve 65 and duct 70 in adapter 55, for circulation through the jacket and ducts 71 in nozzle body 52 in order to cool the combustion chamber and the nozzle. Outlets 72 are provided for withdrawing the cooling water.

The atmosphere composition, high powder velocity and high powder temperature required by the method of this invention can be obtained in the described spray guns by proper control of the operating variables and by proper proportioning of certain parts of the gun.

There are several factors that control powder temperature. Among the more important of these are the nature of the reactants, the fuel-oxygen ratio, the residence time of the coating powder in the burning gases, burner cooling losses, the burner to workpiece distance and powder velocity. Fuels with high flame temperatures, such as acetylene, for example, are desirable and, where permissible, oxygen-fuel ratios that produce maximum flame temperatures should be used. Such ratios may not be used with many coating materials for reasons set forth below, but are suitable for flame-plating ceramic materials.

The coating powder is dependent upon powder velocity as well as on flame temperature for its thermal energy, for the kinetic energy of the particles is effectively converted into thermal energy upon impact on the workpiece. This is shown in the following table of temperature rise on impact, calculated assuming completely inelastic collision.

Temperature rise on impact

Velocity of Powder, ft./sec.	Resultant Theoretical Temperature Increase, °F.
700	160
1,000	320
1,450	680
2,000	1,280
3,000	2,880

The minimum temperature at which powder becomes plastic enough to form a good coating will, of course, depend upon the material used. In any case, however, minimum temperature means the lowest permissible coating temperature of the particle at the time of impact; impact temperature will be the sum of the temperature equivalents of the thermal energy imparted by the flame and the kinetic energy of the powder released upon impact. Thus, even though an otherwise satisfactory fuel may have too low a flame temperature for low velocity processes, it can now be used successfully in the present method because of the additional heat energy added to the coating material upon impact at the high velocities of the present invention.

The nature of the fuel and the oxygen-fuel ratio affect the oxidation potential of the atmosphere, which in turn, affects the composition of the coating. For example, carbon content of certain tungsten carbide powders as supplied is 4.5% to 5.0% by weight. With an oxy-acetylene volume ratio of 1.0, carbon content in the plating was found by combustion analysis to be about 3.0%. At a 1.4 ratio, carbon content was 2.0%, and at a 2.0 ratio, it was 1.3%. Plating quality varied with the carbon content of the coating, as attested by variations in hardness, brittleness and surface appearance. The effective oxidation potential, measured in this instance by decarburization, of various combinations of fuel and oxygen is closely related to the amount of oxidants in the hot burning gases. Oxidants, for example, carbon dioxide and water, may be defined for purposes of this disclosure, as substances having oxidizing properties at the operating temperatures. It has been found that when applying a tungsten carbide plating, for example, the fuel-oxygen ratio should be such that less than 67% by volume of oxidations is formed in the reaction carried to completion, i. e. the ratio of the volume of oxidants to the total volume of products produced by the reaction must be less than 67%. It is particularly important to limit the oxidizing potential of the atmosphere in the use of coating materials readily oxidizable at high temperatures, such as metal and metal carbide, boride, nitride and silicide powders. It is clear that control of the composition of the flame is important in obtaining proper plating qualities.

Various fuels may be used. Acetylene, which has particularly high flame temperatures at fuel-oxygen ratios producing desirable flame compositions, has been found to be especially suitable for use in flame plating. However, other fuels which can meet the temperature and composition requirements are also suitable. For example, hydrogen, methane and ethylene have been used successfully in the flame plating method of this invention.

Powder velocity in a spray gun of the nature described is roughly proportional to gas velocity. Since the supply pressure is the primary determinant of gas velocity, the pressure which can be used becomes an important factor in selection of a fuel. The higher the supply pressure capable of being used with a particular fuel, the higher the attainable powder velocity. Higher powder velocities effectively add thermal energy to the powder. This results from the increased temperature rise upon release of kinetic energy on impact of the powder against the workpiece surface. Thus, fuels permitting higher supply pressures and higher powder velocities may have lower flame temperatures and yet still be practical in the practice of the flame plating method of this invention.

The hardness and porosity of the coating are dependent to a considerable extent upon powder velocity. This is shown in the following table obtained by spraying tungsten-carbide-cobalt alloy with a gun employing a throat combustion burner as shown in Figure 1.

Particle Velocity Feet per Second	Hardness of Coating Knoop Pyramid Number	Porosity
400–600	800–1,000	up to 10%.
600–800 (estimated)	1,000–1,200	approaches 5%.
1,300–1,500	1,100–1,600	less than 2%.

The advantages of high powder velocity and high temperature made available by the present invention are apparent whenever a non-porous, well-bonded coating is desired. These benefits are not limited to any particular coating material, for although the invention is especially adapted for coating with materials of high melting points, it is also adapted for coating surfaces with any of a wide variety of metals, alloys, metallic compounds, plastics, ceramics and minerals. Base surfaces, which may be precleaned in any suitable manner, may also be of a wide variety of materials. The following table shows several illustrative examples of substances which have been plated by this process. Generally the platings were made using 600 cubic feet per hour of oxygen and acetylene in a burner of the type shown in Fig. 1. An oxy-acetylene ratio of 1.0 to 1.6 was employed. In the case of the copper powder, only 300 cubic feet per hour of oxygen

and acetylene were used. The coatings were made in the form of buttons on a flat workpiece.

Workpiece	Powder	Plating Adherence[1]
Steel	Aluminum	Fair.
Do	Cobalt	Good.
Do	Copper	Do.
Do	Iron	Do.
Do	Nickel	Do.
Do	Silicon (−200 mesh)	Fair.
Do	Silver	Excellent.
Do	Tungsten +12% Co (−325 mesh)	Good.
Do	Tungsten carbide +8% Co (−8 micron).	Do.
Do	Tungsten carbide +12% Ni (−10 micron).	Do.
Do	Tungsten carbide +20% Ag (−20 micron).	Do.
Do	Chromium carbide +15% Ni (−10 micron).	Excellent.
Copper	Tungsten carbide +8% Co	Fair.
Stainless Steel	Tungsten carbide +8% Co (−325 mesh).	Good.

[1] The ratings of adherence were made as follows: Fair—examination of cross-sectioned specimens showed a fissure at some point between the plating and the base metal; Good—black inclusions were observed at the base-plating interface in cross-sectioned specimens, although otherwise adherence seemed to be tight; Excellent—bonding of plating to base metal good, with very few or no inclusions at the interface.

An example of the performance of the present invention is its capacity for depositing a substantially non-porous coating of a high melting point, abrasive-resistant hard material such as tungsten carbide compositions. Using a spray gun of the type shown in Figure 1, a tungsten-carbon-cobalt composition containing about 4% carbon and 9% cobalt, in a finely divided powder of the order of 325 mesh was fed into the burner of the gun at a rate of 15 pounds per hour in a hydrogen carrier gas of 60 cubic feet per hour. Acetylene and oxygen at 35 p. s. i. g. were fed to the burner in a ratio of 1.4 cubic feet of the latter to 1 cubic feet of the former at a combined rate of 600 cubic feet per hour. The workpiece, a cylindrical steel piece ½ inch in diameter and 1½ inches in length was rotated at 150 revolutions per minute and advanced ⅛ inch per revolution past the burner outlet, with a standoff distance of 4 inches. In this way the workpiece was coated with a thickness (on the radius) of 0.004 inch in about five seconds. The coated sample was ground and polished by known procedures to a very smooth finish, the hardness of the surface being measured at 1200 Knoop. The gun employed had a water-cooled cylindrical nozzle 9⁄32 inch inside diameter by 8 inches long.

The continuous nature of the present invention makes it possible to apply a steady stream of coating particles against a surface with substantially uniform forces imparted to the particles at all times. In this way, a uniform non-porous coating can be spread over a surface in a relatively short period of operation.

In practice, the gun may be held in either a horizontal or vertical position, and the workpiece to be coated may be moved relative to the gun or the gun may be moved relative to the workpiece. Moreover, in the plating of certain types of work, for example plug gages, the workpiece can be held and rotated in a chuck of the lathe while the gun is moved along the length of the plug. In this way, a uniform layer would be deposited on the gage.

It will be understood that the new features of process operation and gun construction herein disclosed may be employed in ways and forms different from those of the preferred embodiments described above, without departing from the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. A method of applying a surface coating to an object which comprises introducing a solid coating material and a fluid combustible mixture under pressure into a confined combustion space, heating at least a portion of the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of

such material, and thereafter propelling heated coating particles toward the surface of the object to be coated at a linear velocity greater than 500 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to an exit velocity sufficiently high to impart such linear velocity to the particles.

2. A method as described in claim 1, wherein said solid coating material is in comminuted form.

3. A method as described in claim 1, wherein said solid coating material is in the form of a rod.

4. A method of applying a surface coating to an object which comprises introducing a solid coating material and a fluid combustible mixture under pressure into a confined combustion space, heating at least a portion of the coating particles to a high temperature by burning of fluid combustible mixture in said space in the presence of such particles, and thereafter propelling heated coating particles toward the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2000 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to such velocity.

5. A method of applying a surface coating to an object which comprises mixing a fluid fuel and a combustion supporting agent to form a combustible mixture, introducing a comminuted solid coating material into said mixture, introducing combustible mixture containing said comminuted solid material into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter propelling heated coating particles against the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2,000 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to such velocity.

6. A method of applying a surface coating to an object which comprises mixing a fluid fuel containing a comminuted solid coating material with a combustion supporting agent to form a combustible mixture, introducing combustible mixture containing said comminuted solid material into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter propelling heated coating particles against the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2,000 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to such velocity.

7. A method of applying a surface coating to an object which comprises mixing a fluid fuel with a combustion supporting agent containing comminuted solid coating material to form a combustible mixture, introducing combustible mixture containing said comminuted solid material into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter propelling heated coating particles against the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2,000 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to such velocity.

8. A method of applying a surface coating to an object which comprises mixing a fluid fuel and a combustion supporting fluid to form a combustible mixture, introducing a carrier fluid containing comminuted solid coating material into one of such fluids prior to mixing, introducing combustible mixture containing comminuted solid material into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible in said space in the presence of such particles, and thereafter propelling heated coating

particles against the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2,000 feet per second by discharging the particle-carrying burning gases through a confined path in which such gases are accelerated to such velocity.

9. A method of applying a surface coating to an object which comprises continuously introducing a fluid combustible mixture under pressure and a solid coating material into a throat combustion burner wherein combustion of the mixture takes place in the presence of the coating material, passing the burning gases containing coating particles through said burner, discharging particle-carrying burning gases from the burner to develop substantial force for transmission to the particles so as to eject them in a jet flame having a high flame intensity and a high mass velocity, and directing said flame toward the surface to be coated so as to propel heated coating particles at a high linear velocity against such surface to deposit there and build up a coating.

10. A method of applying a surface coating of a high melting point metal composition to an object which comprises suspending such metal composition in finely divided form in a fluid combustible mixture containing oxygen and fuel in proportions to provide upon combustion a non-oxidizing flame, introducing the particle-carrying fluid combustible mixture under pressure into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter propelling heated coating particles against the surface of the object to be coated in a jet flame having a linear exit velocity greater than 2,000 feet per second by discharging the particle-carrying burning gases in a confined path in which such gases are accelerated to such velocity.

11. A method of applying a surface coating to an object which comprises concomitantly introducing a solid coating material and a fluid combustible mixture under pressure into an internal combustion zone from which burning gases are discharged in a jet flame having a linear velocity greater than 2000 feet per second, heating the coating material to a high temperature by burning the fluid combustible mixture in said zone in the presence of such coating material, and directing the flame toward the surface of the object to be coated to propel heated coating particles ejected by and in the flame onto such surface.

12. A flame-spray gun for applying surface coatings to objects, comprising a hollow member defining at least along a portion of its length a throat combustion chamber said chamber having an inlet at one end and an outlet at its other end and a side wall which is continuous from inlet to outlet, said chamber having an entrance portion in which fuel and oxygen under pressure are mixed and combustion is initiated, passage means for supplying fluid fuel and oxygen to said entrance portion of the throat combustion chamber, means for introducing solid coating material into the combustion chamber, said throat combustion chamber having an outlet at least .02 inch in diameter downstream of said entrance portion for discharging coating-particle-carrying burning gases in a jet flame, and said throat combustion chamber extending from said entrance portion to said outlet without constriction in cross-sectional area.

13. A method of applying a surface coating of a metal carbide composition to an object which comprises suspending said composition in finely divided form in a fluid combustible mixture containing oxygen and fuel in proportions to provide upon combustion a non-oxidizing flame and less than 67 percent oxidants in the burning gases, introducing the particle-carrying fluid combustible mixture under pressure into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter projecting heated coating particles against the surface of the object to be coated at at least their flowing temperature by discharging the particle-carrying burning gases in a confined path in which such gases are accelerated to an exit velocity imparting sufficient kinetic energy to the particle so that, together with their thermal energy, the particles will be at least at such flowing temperature upon impact.

14. A method of applying a surface coating of a tungsten carbide composition to an object which comprises suspending said tungsten carbide composition divided to a powder finer than 325 mesh in a fluid combustible mixture containing oxygen and acetylene in a ratio between 0.8:1 and 1.9:1, introducing the particle-carrying fluid combustible mixture under pressure into a confined combustion space, heating the coating particles to a high temperature by burning the fluid combustible mixture in said space in the presence of such particles, and thereafter projecting heated coating particles against the surface of the object to be coated at at least their flowing temperature by discharging the particle-carrying burning gases in a confined path in which such gases are accelerated to an exit velocity imparting sufficient kinetic energy to the particles so that, together with their thermal energy, the particles will be at least at such flowing temperature upon impact.

15. A flame spray gun comprising a hollow member having at least along a portion of its length an internal combustion throat passage defined by walls extending from an inlet zone at one end to an outlet at its other end, said passage extending from the inlet zone to the outlet without constriction in cross-sectional area and being at least .02 inch in diameter downstream of said inlet zone, means for supplying fluid combustible to said inlet zone comprising first and second conduits supplying fluid fuel and fluid oxidant each under pressure, said conduits terminating respectively in delivery orifices disposed adjacent each other and said inlet zone on the upstream side thereof, said delivery orifices being arranged for delivering the oxidant and fuel streams to intersect at a substantial angle to each other for rapid mixing and combustion in said throat passage; and means for introducing solid material into said internal combustion throat passage wherein the material is heated to a high temperature and particle carrying burning gases are discharged from the outlet in a jet flame.

16. A flame spray gun according to claim 15 in which said means for introducing solid material comprises means for feeding a comminuted solid material with one of said oxidant and fuel gas streams to said inlet zone.

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